Phase Transformations in $(Mg,Fe)_2SiO_4$ System at Low Temperatures: an *In-situ* X-ray Diffraction Study

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Introduction: Knowledge of the kinetics and mechanisms of the transformation of olivine to its high pressure polymorphs (wadsleyite and ringwoodite) under subduction zone conditions is important for understanding the dynamics of subduction, the mechanism of deep earthquakes, and the mechanical properties of subducting lithosphere. Although there have been many experimental investigations of these transformations, most studies were conducted using quenching technique on analogue materials or on olivine at high temperatures. The depth where the phase transition occurs in subducting slabs is not well constrained due to the large uncertainties in extrapolating laboratory experimental results to conditions in subducting lithosphere. We have initiated a research project studying the transformational characteristics of mantle olivine to its high-pressure polymorphs in the pressure and temperature domain of a subducting slab (i.e., high pressures and low temperatures).

Methods and Materials: After the sample was compressed to the target pressure (P) using the multi-anvil press SAM85 coupled with a T-Cup device, temperature (T) was increased to the desired value. The phase transformations were monitored by collecting time-resolved X-ray diffraction patterns using the synchrotron radiation at beamline X17B1 while the sample remained under the same P, T conditions. This in-situ x-ray technique has the capability of tracing the P-T path of each run, an advantage over the quenching technique. The starting materials included San Carlos olivine and olivines with similar compositions from the Four Corners area in the southwestern USA. Powder NaCl was used as the pressure standard.

Results: (1) For cold-compressed powder samples, the olivine-ringwoodite transformations were observed within minutes to a few hours between 600-650°C at 15-18 GPa (Fig. 1). (2) An olivine sample pre-heated at 850 °C and 1 bar for two hours in Ar flow was completely transformed to ringwoodite within 30 minutes at 550 °C and 16 GPa (Fig. 2). (3) When a pre-annealed (1200 °C and 3 kbar) olivine sample and an olivine powder were run together at 850 °C and 15 GPa, no significant differences were found for the kinetics of phase transformation in the two samples. (4) No significant difference was found for an olivine containing about 50 ppm H_2O and a sample containing no significant amount of H_2O in a comparison run.

Conclusions: The phase transformations in $(Mg,Fe)_2SiO_4$ system have been observed at relatively low temperatures. The defects in olivine samples created during the cold compression and those related to the oxidation have significant effect on the kinetics of transformation, and may play dominant roles when compared to the effect of low-density, OH-related imperfections. Some of our results show considerable differences from those obtained using quenching technique. The reason for the discrepancy is under investigation. This study indicates there are many controlling factors for the kinetics of phase transformations in $(Mg,Fe)_2SiO_4$ system. Caution should be taken when one applies laboratory results to the subduction zones.

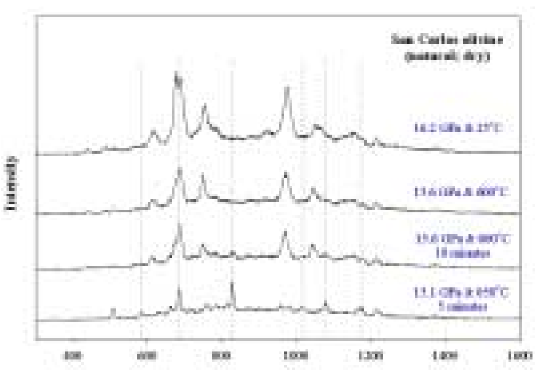

Figure 1. Time-resolved diffraction patterns for San Carlos natural olivine at different conditions. The dashed lines indicate the diffraction peaks of ringwoodite.

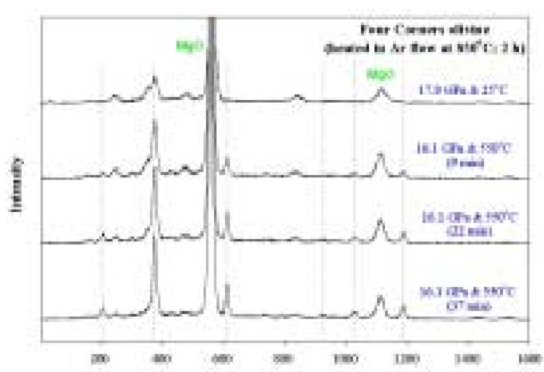

Figure 2. Time-resolved diffraction patterns for an olivine sample pre-heated in Ar flow at 850°C for 2 hours. The dashed lines indicate the diffraction peaks of ringwoodite.